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Design and Implementation of the Management and Detection System of Dangerous Production Raw Materials Based on Odor Sensor Technology

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With the rapid development of electrification, both productivity and human civilization have made rapid progress and electrification has led to more and more fires. Therefore, it is of great significance to strengthen the investigation and prevention of fires, especially the confirmation of the origin of fire. Considering the post-combustion residual characteristics of common flammable production raw materials (carbon dioxide and dust) at the scene of the fire, this paper designs a detection system based on odor sensor for rapid detection, data analysis and recognition. The system designs a multi-function sensor array for detecting dangerous production raw materials (carbon dioxide and dust), and develop a good method for spot sampling. It introduces embedded technology and uses it together with chromatographic technology and sensor array, achieving the accurate detection of the combustion residues of dangerous production raw materials (carbon dioxide and dust) is realized. The detection signals are post-processed by feature extraction technology and pattern recognition algorithm. The research results are helpful for rapid analysis and recognition of residues, providing certain technical support for the recognition for the cause of fire.

1. Introduction

With the continuous development of the social economy, urbanization, building scale and population density have also developed rapidly. In recent years, the frequency of major fires in urban area has been increasing. On the one hand, it has led to public economic losses and casualties; on the other hand, it is also not conducive to social harmony and stability (Jin et al., 2011; Wakimoto and Suzuki, 2013). Therefore, after the fire, it is necessary to find out the cause earnestly, quickly and accurately so as to better prevent fire accidents in the future. According to the long-term front-line practical experience, the most common flammable production raw materials at the scene of fire are carbon dioxide and dust. If improperly stored or operated and the dust concentration exceeds the standard, it is easy to result in fire accidents after mixing carbon dioxide (Bahraminejad et al., 2010; David et al., 2009; Cao, 2018).

Therefore, it is extremely urgent to design a detection device with high accuracy and easy operation from the residues of flammable raw materials such as carbon dioxide and dust. The detection devices used at this stage have high accuracy, but these devices usually have a large volume and the operation is very complicated. Moreover, there is difficulty in on-site real-time detection. In view of this, this paper attempts to combine the chromatographic technology and sensor array to design a portable real-time detection instrument for flammable raw material residues in the scene of fire, thus providing more support for fire site detection.

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2. Key technologies of system design

2.1 Odor sensor technology

The odor sensor is also known as electronic nose and odor scanner in the industry, which is an intelligent biomimetic sensor system (Baoquan et al., 2015; Tamanini, 2002; Atkinson, 1994; Hu, 2018). JWGardner has given clear definition for this: the electronic nose is a selectable combination of electrochemical sensor arrays and recognition devices that can identify a wide range of odors (Fomin and Chen, 2008; Jia et al., 2014; Gao and Levent, 2016). The electronic nose generally has two main parts: one is the sensor array, and the other is the recognition system. In the process of selecting the recognition system, it is necessary to ensure that it conforms to the function that is actually used, so as to identify the odor qualitatively and quantitatively and satisfy the recognition of a variety of mixed odors (Kim et al., 2012; Sysoev et al., 2011). The theory of constitution of the olfactory sense of human beings and electronic nose is shown in Figure 1.

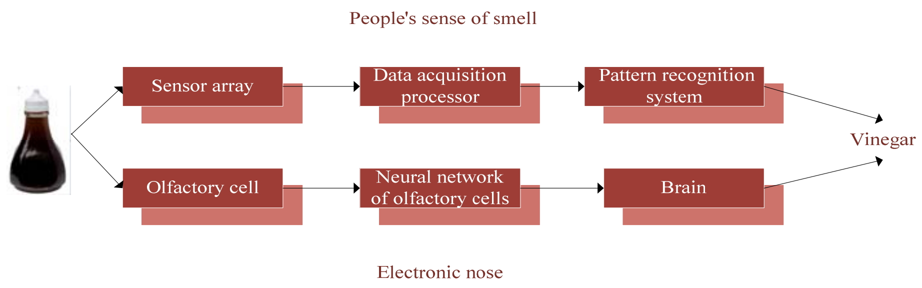


Figure 1: A schematic diagram of human olfactory sense and electronic nose

2.2 Gas chromatography separation technology

Gas chromatography can accomplish the separation of components within the mixture. It requires the use of stationary phases such as solid adsorbents and liquids to complete the work and the gas that does not react with the stationary phase exists in the form of mobile phase (D'Hulst et al., 2016; Ji et al., 1999). Different components have different characteristics, so there is a certain difference in the adsorption resistance between each component and its stationary phase. Based on the same driving force, each component flows out the chromatographic column based on the corresponding sequence (Roppel and Wilson, 2000). This technology distributes different components of the chromatographic column stationary phase, so that multiple distributions are made in these components to ensure the difference in flow rate, thus finally completing the separation.

3. Detector design of flammable dangerous production raw materials residues

3.1 Overall design of the detector

Due to the lack of selectivity of a single sensor, in this detector design process, we do not choose a single sensor, but a sensor array, which contains a number of different sensors. Moreover, it is combined with chromatographic separation technology. Combining the advantages of these two technologies, the device has good selectivity and sensitivity. It is also more stable and has stronger anti-interference ability. The principle is shown in Figure 2, including different modules such as sensor array and signal analysis.

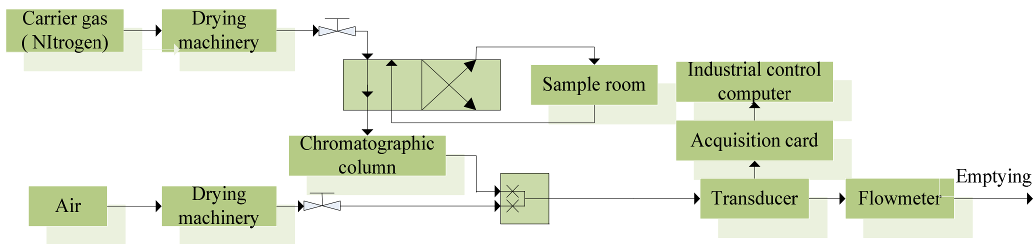


Figure 2: Schematic diagram of detector

3.2 Sensor selection and sensor array

In the entire design of the detection system, the sensor is the most important, which can realize the conversion of physical signals, so that it exists in the device in the form of electrical signals. Semiconductor gas sensors are widely used in the industry, among which the Figaro metal oxide semiconductor sensor has obvious advantages in many aspects such as sensitivity, power consumption, cost, and service life. Therefore, it is widely used in various fields such as indoor air detection.
In the process of gas detection, a single sensor faces many limitations. However, the sensor array can take advantage of the complementarity between sensors, so that the sensor has good selectivity. Five different sensors are used in the system design process, namely four Ferro series metal oxide semiconductor sensors and a photoionization detector. The technical parameters are shown in Table 1. When the gas flows into the sensor, the sensor array will give a response curve. After these curves are combined, it can achieve the recognition of residues with the help of recognition algorithm.

Table 1: The technical parameters of the sensor selected in this system

Product model	Usage	Main detection gas	Detection concentration range	working voltage	Rate of work
TGS211	Combustible gas, harmful gas	Alkane, hydrogen	100~1000mmp	DC5V	<750mW
TGS135	Harmful gas	Aromatic compounds, ethanol	10~300ppm	DC5V	<800mW
TGS2620	Solvent vapors	Alcohol, organic solvents	50~5000ppm	DC5V	280mW
TGS2600	Air quality inspection	Alcohol, hydrogen	1~10ppm	DC5V	210mW
PID-AH	VOC	Methane, isopropylene	5ppb~50ppm	DC3.6~20V	110mW

After selecting the type of sensor, these five types of sensors should be reasonably combined and exist in the form of sensor array to ensure that the detected gas can form a corresponding response signal. Meanwhile, a signal acquisition card is used for signal collection and it is displayed on the tablet industrial computer. The circuit diagram is shown in Figure 3, in which R1, R2, R3 and R4 represent metal oxide semiconductor sensors. When detecting the gas, its resistance will change accordingly. Generally, the between gas concentration and resistance are inversely proportional with each other. Therefore, in the schematic diagram, a variable resistor can be used to represent the sensor.

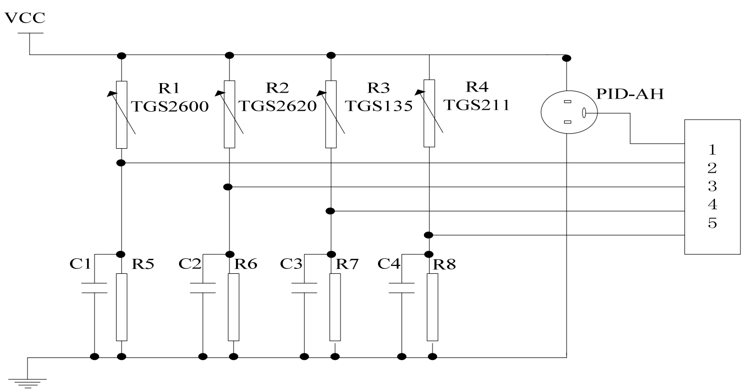


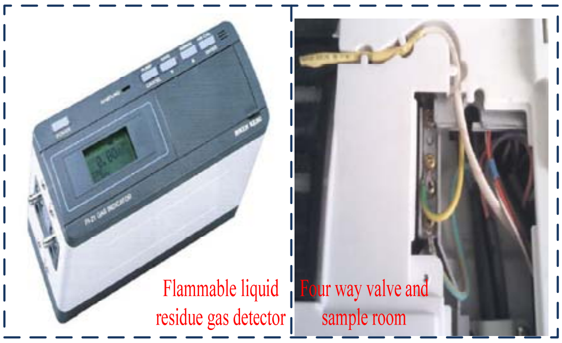
Figure 3: Sensor array circuit diagram

3.3 Gas chromatographic separation

For different analysis objects, various suitable chromatographic columns should be used in the recognition process. Dust is highly prone to explosion at high temperature and high concentration because a portion of it has a high specific surface area and more importantly, it has high-temperature volatile components. It is easy to find out after the test comparison that the SE-30 chromatographic column can detect 8 peaks after separation. At the same time, it is also possible to locate the position of different peaks. Therefore, a packed chromatography column is selected this time.

3.4 Operation process and experiment summary

Figure 4 shows the most commonly used gas detector for flammable and explosive raw material residues:



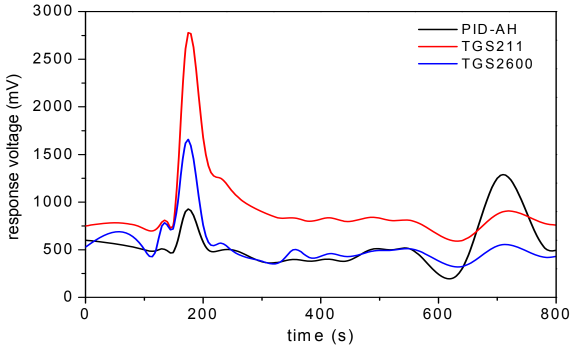


Figure 4: Physical effect diagram of testing instrument *Figure 5: Response signal of residual gas after combustion of gasoline mixed with interferences*

The operation steps are as follows:
(1) Ensure that the power supply is turned on to achieve the purpose of preheating the sensor array. Then, open the pressure regulating valve so that the air and carrier gas can enter it. After drying, the carrier gas flows into the chromatographic column and it will pass the sensor array together with the air.
(2) After the response signal is stabilized, the sampling tube is placed in the sampling chamber, and the gas to be detected on the tube will be volatilized. This treatment can be carried out by high temperature desorption.
(3) Open the collection level and the four-way valve so that the carrier gas can flow into the chromatographic column carrying the detected gas. The adsorption degree of the different substances by the stationary phase in the chromatographic column is different. Therefore, the mixed component can flow according to the correspondingly sequence and the gas is separated in the process.
(4) In the sensor array, there will be a chemical reaction after the gas flows in. When the sensor detects the substance, a corresponding response signal will be generated according to the characteristics and categories of different substances; the signal passes through the filter circuit through the partial pressure in the sampling resistor and it can finally be displayed on the industrial control computer.
(5) Different response curves will be arrayed on the industrial control computer. When collecting the gas, it is necessary to make sure that the acquisition time is the same. In this experiment the acquisition time is set to 800s. After the detection is completed, the data files need to be stored.
Through the experiment, we can obtain the response curves of carbon dioxide, dust volatile gases and residual gases after burning with common flammable interferents, as is shown in Figure 5:
It can be known according to the analysis of the experimental results that the detector developed this time can clearly detect the components such as benzene, toluene and xylene contained in the flammable raw materials (carbon dioxide and dust). Therefore, the qualitative analysis of the flammable raw materials can be realized with the aid of this. In addition, during the detection, when the residue after combustion is detected again, the dust component can still be found in the detection. Therefore, in the process of practice, the presence of flammable production materials at the scene can be judged by the detection result of residues.

4. Data acquisition and real-time display implementation

The designed device is of small volume and good portability, which can better detect the residue of flammable raw materials at the scene. Therefore, it is necessary to combine the embedded technology to achieve the complete detection.

4.1 Embedded devices

The embedded device produced by produced Altai is selected in the design process. This computer has multiple functions and embedded system interfaces, which can realize the full operation of the embedded operating system and the sufficient resource storage. The acquisition module can be connected to it to form an acquisition component. The acquisition card used has great flexibility and the RS485 network can be built with only two signal lines.

4.2 Development environment construction

To complete the construction of the entire environment, the VisualStudio2005, WindowsEmbeddedCE6.0 and WINCE6.0R2 need to be installed. After the environment is set up, it is connected to the interface so that the communication connection can be established between the development board and the machine, thereby better performing file operations and remote debugging.

4.3 System software design

The software design of this system is divided into three major modules, namely: program initialization module; data acquisition and storage module; real-time display module of response signals. The core of the program initialization is to reset the system or to conduct the initial setting after power-on. Data acquisition and storage are mainly for the acquisition, conversion and preservation of five analog signals. The real-time display shows five signals in the display screen with five different colors. The specific process is shown in Figure 6:

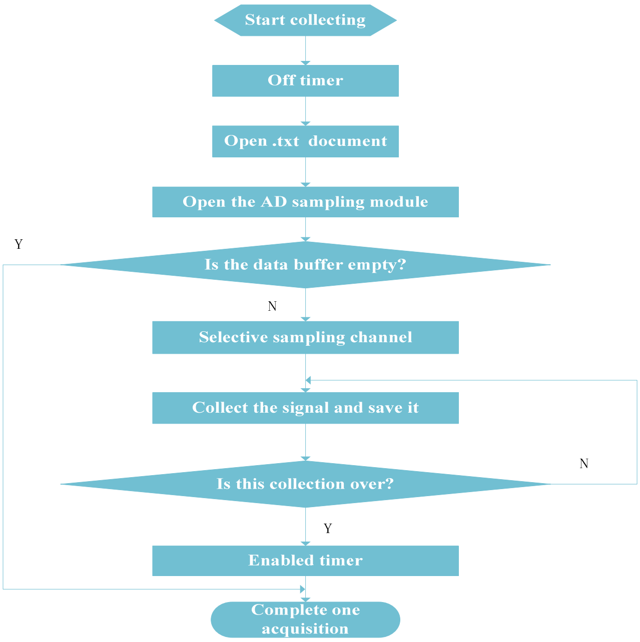


Figure 6: Data collection and storage flow chart

After completing the compilation and linking of the software, we can obtain an executable program on its target platform and it can run after downloading. In this design, the system is designed with the function of automatic opening and this function is used in this experiment. Therefore, after connecting the power of the detector, the startup program interface will automatically skip, as is shown in Figure 7:

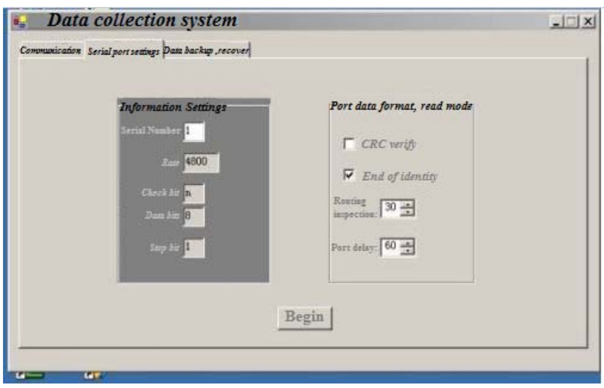


Figure 7: Data acquisition system interface diagram

According to the analysis of the final result of the on-site simulation test, the portable detector designed this time can satisfy the daily detection requirements of the flammable production raw materials and the response signal formed after combustion.

5. Conclusion

(1) This paper designs and develops a gas detector device for flammable production raw material residues that combines the chromatographic separation technology with sensors, which can detect various flammable production raw materials and combustion residues.
(2) The embedded technology is utilized in the design process to achieve a good combination with the industrial control tablet. During the on-site detection, the signal can be displayed in real time to ensure the portability of the device.
(3) This paper completes the design and implementation of the sampling system. The gas to be detected can be inhaled, so that it can separate the sampler from the detecting device and real-time control can be performed on the gas sampling.

Acknowledgments

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